

**PRODUCTION AND USE OF A  
PREMIUM FUEL GRADE PETROLEUM COKE**

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**BACKGROUND OF THE INVENTION**

**1. Field of the Invention**

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This invention relates generally to the field of petroleum coking processes, and more specifically to modifications of petroleum coking processes for the production of a premium-quality, "fuel-grade" petroleum coke. This invention also relates generally to the use of this new formulation of petroleum coke for the production of energy, and more specifically to modifications in conventional, solid-fuel furnaces and environmental control systems to take optimal advantage of its unique properties.

**2. Description of Prior Art**

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Since initial efforts to refine crude oil in the U.S. during the late 1800s, the search for an appropriate use for the heaviest fractions of crude oil (i.e. the "bottom of the barrel") has been a perplexing problem. Initially, many refineries received little to no value from the heaviest fractions of crude oil. Some were noted to simply discard the "bottom of the barrel." Over time, some of the heavy crude oil fractions were used in asphalt products and residual fuel oils. However, the demand for these products was not sufficient to consume increasing production.

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As demand for transportation fuels (e.g. gasoline, diesel, and aviation fuels) increased in the early 1900s, thermal cracking processes were developed to convert the

heavy crude oil fractions into lighter products. These refinery processes evolved into the modern coking processes that predominate the technology currently used to upgrade the heaviest fractions of the crude oil. These processes typically reduce the quantity of heavy oil fractions, but still produce unwanted by-products (e.g. petroleum coke) with marginal value.

A. Production of Petroleum Coke; Coking Processes:

In general, modern coking processes employ high-severity, thermal decomposition (or "cracking") to maximize the conversion of very heavy, low-value residuum feeds to lower boiling hydrocarbon products. Coker feedstocks typically consist of non-volatile, asphaltic and aromatic materials with "theoretical" boiling points exceeding 1000° F at atmospheric pressure. The boiling points are "theoretical" because these materials coke or crack from thermal decomposition before they reach such temperatures.

Coking feedstocks normally consist of refinery process streams which cannot economically be further distilled, catalytically cracked, or otherwise processed to make fuel-grade blend streams. Typically, these materials are not suitable for catalytic operations because of catalyst fouling and/or deactivation by ash and metals. Common coking feedstocks include atmospheric distillation residuum, vacuum distillation residuum, catalytic cracker residual oils, hydrocracker residual oils, and residual oils from other refinery units. Consequently, coking feedstocks vary substantially among refineries. Their composition and quantity primarily depend on (1) the input crude oil blend, (2) refinery processing equipment, and (3) the optimized operation plan for any particular refinery. In addition, contaminant compounds, which occur naturally in the crude oil, generally have relatively high boiling points and relatively complex molecular structures. Consequently, these contaminant compounds, containing sulfur and heavy metals, tend to concentrate in these residua. Many of the worst process streams in the

refinery have become coker feedstock, and their contaminants usually end up in the petroleum coke by-product. For this reason, the coking processes have often been labeled as the "garbage can" of the refinery.

5           There are three major types of modern coking processes currently used in refineries to convert the heavy crude oil fractions into lighter hydrocarbons and petroleum coke: Delayed Coking, Fluid Coking<sup>R</sup>, and Flexicoking<sup>R</sup>. In all three of these coking processes, the petroleum coke is considered a by-product that is tolerated in the interest of more complete conversion of refinery residues to lighter hydrocarbon  
10       compounds, referred to as "cracked liquids" throughout this discussion. These cracked liquids range from pentanes to complex hydrocarbons with boiling ranges typically between 350 and 950 °F. The heavier cracked liquids (e.g. gas oils) are commonly used as feedstocks for further refinery processing that transforms them into transportation fuel blend stocks.

15           The delayed coking process has evolved with many improvements since the mid-1930s. Essentially, delayed coking is a semi-continuous process in which the heavy feedstock is heated to a high temperature (between 900 °F and 1000 °F) and transferred to large coking drums. Sufficient residence time is provided in the coking  
20       drums to allow the thermal cracking and coking reactions to proceed to completion. The heavy residua feed is thermally cracked in the drum to produce lighter hydrocarbons and solid, petroleum coke. One of the initial patents for this technology (U.S. Patent 1,831,719) discloses "The hot vapor mixture from the vapor phase cracking operation is, with advantage, introduced into the coking receptacle before its  
25       temperature falls below 950 °F, or better 1050° F., and usually it is, with advantage, introduced into the coking receptacle at the maximum possible temperature." The "maximum possible temperature" in the coke drum favors the cracking of the heavy residua, but is limited by the initiation of coking in the heater and downstream feed lines, as well as excessive cracking of hydrocarbon vapors to gases (butane and

lighter). When other operational variables are held constant, the "maximum possible temperature" normally minimizes the volatile material remaining in the petroleum coke by-product. In delayed coking, the lower limit of volatile material in the petroleum coke is usually determined by the coke hardness. That is, petroleum coke with < 8 wt. % volatile materials is normally so hard that the drilling time in the decoking cycle is extended beyond reason. Various petroleum coke uses have specifications that require the volatile content of the petroleum coke by-product be < 12%. ~~Consequently, the volatile material in the petroleum coke by-product typically has a target range of 8-12 wt. %.~~ Prior art in the delayed coking process, including recent developments, has attempted to maximize the production of cracked liquids with less coke production. In this manner, the prior art of delayed coking has attempted to minimize coke yield and the amount of volatile materials it contains.

Fluid Coking<sup>R</sup>, developed since the late 1950s, is a continuous coking process that uses fluidized solids to increase the conversion of coking feedstocks to cracked liquids, and further reduce the volatile content of the product coke. In Fluid Coking<sup>R</sup>, the coking feedstock blend is sprayed into a fluidized bed of hot, fine coke particles in the reactor. Since the heat for the endothermic cracking reactions is supplied locally by these hot particles, this permits the cracking and coking reactions to be conducted at higher temperatures (about 480-565 °C or 900-1050 °F) and shorter contact times than in delayed coking. Roughly 15-25% of the coke is burned in an adjacent burner vessel in order to create the hot coke nuclei to contact the feed in the reactor vessel, and satisfy the process heat requirements. The Fluid Coking<sup>R</sup> technology effectively removes the lower limit of volatile content in the petroleum coke, associated with delayed coking. The volatile content of the petroleum coke produced by the Fluid Coking<sup>R</sup> technology is typically minimized (or reduced), within the range of 4-10 wt. %. Consequently, the quantity of petroleum coke, produced by a given feedstock, and its volatile content are significantly reduced in the Fluid Coking<sup>R</sup> technology (vs. delayed coking).

As noted above, many operational variables *indirectly* affect the coke VCM. As such, the selection of the appropriate modifications in the delayed coker operating conditions is not straightforward. In many cases, changes in the feedstock gravity and reductions in coker cycle time tend to increase the coke VCM, but provides limited change in VCM quality. Increases in drum pressure tend to increase the quality and quantity of coke VCM, but can be difficult to control coke VCM within a narrow target range. The reduced steam stripping in the decoking cycle has been noted to have limited effect on coke VCM content. However, reduced coke drum temperatures tend to increase and maintain both the quality and quantity of coke VCM. Reduced coke drum temperatures can decrease the cracking reactions, increasing unreacted feedstock and partially cracked components. In most cases, it provides a lower vaporization temperature in the coke drum, leaving lighter cracked or unreacted hydrocarbon components (i.e. higher quality VCM) integrated in the coke. In addition, the coke VCM content can be more predictable via reduced drum temperatures (vs. other operational variables). As such, coke VCM content can be readily controlled within a specified range. Furthermore, reduced coke drum temperatures have the added benefit of improving the coke crystalline structure (See below). Consequently, reduced coke drum temperatures was selected as the preferred means of increasing coke VCM to achieve the objectives of the present invention.

Based on this analysis, the simplest and preferred means of increasing and maintaining the volatile content of the coke (i.e. to a consistent level between 13 and 50 wt. % VCM) would result from a reduction of the average drum temperature by 5-80 °F (preferably 5-40 °F). That is, an average drum vapor line temperature of 770 to 850 °F can provide VCM levels of 15-30% for many coker feedstocks. However, as noted earlier, coker feedstocks vary considerably among refineries, and can attain 15-30% VCM outside of this temperature range. In these situations, the relative temperature drop from the existing average drum temperature is expected to be

Basis =  $1.0 \times 10^9$  Btu/Hr Heat Release Rate as Input

<u>Fuel Characteristics</u>		<u>Current Coal</u>	<u>Upgraded coke</u>	
<u>Results</u>				
Lower	VCM (%wt)	40.0	16.0	60%
	Ash (%wt.)	9.1	0.3	97%
	Moisture (%wt.)	3.6	0.3	92%
	Sulfur (%wt)	4.0	4.3	8%
Higher	Heating Value (MBtu/lb)	12.9	15.3	19%
	Fuel Rate (Mlb/Hr)	77.8	65.4	16%
<u>Pollutant Emissions: Uncontrolled/Controlled</u>				
Lower	Ash Particulates (lb/MMBtu or Mlb/Hr)	7.1/0.4	0.2/0.1	97%
	Sulfur Oxides (lb/MMBtu or Mlb/Hr)	6.2/6.2	5.6/6	90%
Lower	Carbon Dioxide (lb/MMBtu or Mlb/Hr)	238	210	12%

This example demonstrates major benefits from the application of the present invention. The upgraded petroleum coke has substantially lower ash and moisture contents, compared to the existing coal. These factors contribute greatly to (1) the ability to burn successfully with lower VCM and (2) a fuel heating value that is 19% higher. In turn, the higher heating value requires a 16% lower fuel rate to achieve the heat release rate basis of one billion Btu per hour in the boiler. As noted previously, this lower fuel rate and the softer sponge coke significantly reduce the load and wear on the fuel processing system, while increasing the pulverizer efficiency and improving combustion characteristics.

The ash particulate emissions (ash from the fuel) are 97% lower than the existing coal, due to the lower ash content and higher fuel heating value. In this manner, fuel switching to the upgraded coke unleashes 97% of the capacity in the

operating conditions for a particular coker feedstock blend and particular product specifications for the downstream processing requirements. The series of pilot plant studies are typically designed to produce empirical data for operating conditions with variations in feedstock blends and liquid product specification requirements. Consequently, the fluid coker designs and target operating conditions vary significantly among refineries.

In normal fluid coker operations, various operational variables are monitored and controlled to achieve the desired fluid coker operation. The primary operational variables that affect coke product quality in the fluid coker are the reactor temperature, reactor residence time, and reactor pressure. The reactor temperature is controlled by regulating (1) the temperature and quantity of coke recirculated from the burner to the reactor and (2) the feed temperature, to a limited extent. The temperature of the recirculated coke fines is controlled by the burner temperature. In turn, the burner temperature is controlled by the air rate to the burner. The reactor residence time (i.e. for cracking and coking reactions) is essentially the holdup time of fluidized coke particles in the reactor. Thus, the reactor residence time is controlled by regulating the flow and levels of fluidized coke particles in the reactor and burner. The reactor pressure normally floats on the gas compressor suction with commensurate pressure drop of the intermediate components. The burner pressure is set by the unit pressure balance required for proper coke circulation. It is normally controlled at a fixed differential pressure relative to the reactor. The following target control ranges are normally maintained in the fluid coker for these primary operating variables:

1. Reactor temperatures in the range of about 950°F to about 1050°F,
2. Reactor residence time in the range of 15-30 seconds
3. Reactor pressure in the range of about 0 psig to 100 psig: typically 0-5 psig,
4. Burner Temperature: typically 100-200°F above the reactor temperature

These traditional operating variables have primarily been used to control the quality of the cracked liquids and various yields of products, but *not* the respective quality of the byproduct petroleum coke.

C. Process Control of the Present invention:

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The primary improvements of the present invention are modifications to the operating conditions of the Fluid Coking<sup>R</sup> process, in a manner that is not suggested by prior art. In fact, these changes in operating conditions are contradictory to the teachings and current trends in the prior art. As noted previously, the operating conditions of the prior art give first priority to maximizing cracked liquid products. The operating conditions of the present invention give first priority to consistently increasing the volatile combustible material in the resulting petroleum coke to 13-50 wt. % VCM (preferably 15-30% VCM). Second priority is given to consistently provide a minimum-acceptable level of coke crystalline structure in the product coke. The third priority is THEN given to maximize coker throughput and/or the conversion of coker feedstock blend to cracked liquid products. However, changing the VCM content and crystalline structure in fluid coke is much more challenging, relative to delayed coke. The operating conditions required to achieve the objectives of the present invention were moderate, yet specific changes relative to the prior art.

As discussed previously, fluid coker operating conditions vary greatly among refineries, due to various coker feedstocks, coker designs, and other refinery operations. Therefore, specific operating conditions (i.e. absolute values) for various refinery applications are not possible for the present invention. However, specific changes relative to existing operating conditions provide specific methods of operational change to achieve the desired objectives

INCREASED VOLATILE COMBUSTIBLE MATERIAL (VCM) IN FLUID<sup>R</sup> COKE: In a manner similar to the delayed coking process, reduction in the process operating temperature will cause an increase of volatile combustible material in the resulting petroleum coke. That is, the reduction in process (or reactor) temperature will reduce the cracking and coking reactions, and thereby, leaving more unreacted coker feedstock and cracked liquids in the coke as volatile combustible material. However, the different mechanism of coking in the

engineered solutions to treat the coke after the coking process. Options for this embodiment might include various physical, chemical, and/or biological treatments. Another option may also use the transportation and storage of the coke to increase treatment time. This option may require final treatment steps, rinsing, and water treatment systems at the coke user's facility.

**COKER FEEDSTOCK DILUTION:** Another embodiment of the present invention would modify the coker feedstocks to reduce the concentration of contaminants in the final coke product. Coke-producing feedstocks with lower concentrations of the contaminants of concern would be added to the coker feed to dilute the concentration of contaminants in the petroleum coke product.

**COKER FEEDSTOCK PRETREATMENT:** Yet another embodiment of the present invention may include other types of coker feedstock pretreatment. From a technical perspective, the addition of a coker feed pretreatment system would likely be the most effective means of addressing the detrimental impacts of petroleum coke contaminants. However, this embodiment often is not economically optimal. The optimal coker feed treatment system would depend on the composition of the coker feedstocks and the needs of the petroleum coke user. After the degree of required decontamination and the impacts of feed treatment decontamination are known, various engineered solutions would be available to treat the coker feedstocks. This coker feed treatment system may or may not include more sophisticated demetallization and/or desulfurization technologies, described in the prior art. For example, hydrotreating or hydrodesulfurization of the coker feedstocks can decrease the sulfur content by 80-95%. If most of the sulfur is removed from the product coke in this manner, the excess capacity of in a utility boiler's existing particulate control device can be used for the collection of other gases (e.g. carbon dioxide) that are converted to collectible particulates. Also, desulfurization of the coker feedstock may provide further advantage by increasing coke VCM and promoting sponge coke.

#### CURRENT REFINERY OPERATION WITH NO FURTHER DECONTAMINATION:

Another embodiment of the present invention may include no treatment of any kind for decontamination of the coke. As noted previously, the effects of petroleum coke's high metals content in combustion and heat transfer equipment is not well understood or defined. The design and operation of the user's combustion system plays a major role in determining whether the current level of contaminants in the coke is acceptable or not. Therefore, some oil refineries, depending on the coker feedstock blend and coker operation, may be able to provide the upgraded petroleum coke without further coke decontamination.

#### GENERAL ISSUES FOR EMBODIMENTS OF LOW-LEVEL

DECONTAMINATION: After the specific level of required coke decontamination is determined for any given product coke, engineering will determine the optimal use for any of the above embodiments, separately or in combination. The combination of any of these embodiments may reduce the level of decontamination required by each embodiment, individually. Finally, these concepts and embodiments may be applied to other types of coking and desalting processes, available now or in the future.

### **3. Production of Premium "Fuel-Grade" Petroleum Coke: *Optimized Fuel Embodiment***

The various methods and embodiments of the present invention can also be used to optimize combustion characteristics for specific combustion applications. The following embodiment provides a means to produce an upgraded petroleum coke that not only achieves the basic objectives of this invention, but also optimizes fuel characteristics to replace existing solid fuels with the least (or lower) amount of equipment and operational modifications. As noted earlier, one fuel can be directly substituted for an existing fuel in a full-scale operation, if the burning characteristics are sufficiently similar. As such, the various techniques, used in this invention to create a premium petroleum coke, can be optimized in many cases to produce a direct replacement fuel for existing facilities. In this manner, a specific coker with certain

Basis =  $1.0 \times 10^9$  Btu/Hr Heat Release Rate as Input

<u>Fuel Characteristics</u>	<u>Current Coal</u>	<u>Upgraded coke</u>	<u>Results</u>
VCM (%wt)	44.2	20.0	54% Lower
Ash (%wt.)	10.8	0.3	97% Lower
Moisture (%wt.)	17.6	3.8	78% Lower
Sulfur (%wt)	4.3	5.2	21% Higher
Heating Value (Mbtu/lb)	10.3	14.2	38% Higher
Fuel Rate (Mlb/Hr)	97.0	70.4	27% Lower

**Pollutant Emissions: Uncontrolled/Controlled**

Ash Particulates (lb/MMBtu or Mlb/Hr)	10.5/.53	.18/.01	98% Lower
Sulfur Oxides (lb/MMBtu or Mlb/Hr)	8.4/.84	7.4/.15	82% Lower
Carbon Dioxide (lb/MMBtu or Mlb/Hr)	245	214	13% Lower

This example further demonstrates the beneficial application of the present invention. Again, the upgraded petroleum coke has substantially lower ash and moisture contents, compared to the existing coal. These factors contribute greatly to (1) the ability to burn successfully with lower VCM and (2) a fuel heating value that is 38% higher. In turn, the higher heating value requires a 27% lower fuel rate to achieve the heat release rate basis of one billion Btu per hour in the boiler. As noted previously, this lower fuel rate and the softer sponge coke significantly reduce the load and wear on the fuel processing system, while increasing pulverizer efficiency and improving combustion properties.

The ash particulate emissions (ash from the fuel) are 98% lower than the existing coal, due to the lower ash content and higher fuel heating value. Consequently, fuel switching to the upgraded coke unleashes 97% of the capacity in the existing particulate control device. This excess capacity can now be used for the control of sulfur oxides via retrofit FGC

applications. The present invention anticipates effective integration of this technology. Similar to the previous embodiment, the upgraded coke of the present invention has many desirable characteristics of the activated carbon. In many cases, the upgraded coke can be readily modified to be effectively used as the activated coke. Again, the coke loses activation after numerous cycles of use and regeneration. Apparently, this occurs more quickly in the high-sulfur applications. Deactivated coke can then be blended into coke fuel and subsequently burned in the combustion system.

In a similar manner, the upgraded coke of the present invention can be used for activated carbon technologies for the removal of air toxics (e.g. mercury), carbon dioxide, or other undesirable flue gas components. The activated carbon technologies for these components system can be integrated (1) fully into the SOx/NOx activated coke system (to the extent possible), (2) share auxiliary systems, or (3) work independently with or without the SOx/NOx activated coke system. In any case, deactivated coke can be blended into the coke fuel and subsequently burned in the combustion system.

**E. EXAMPLE 3: Low-Sulfur Lignite Coal vs. Medium Sulfur Coke with Dry Sorbent Injection**

Another power utility has a conventional, pulverized-coal fired utility boiler that currently burns a low-sulfur, lignite coal from Texas. The existing utility has a large-capacity, particulate control device with no sulfur oxides control. Full replacement of this coal with a medium-sulfur, petroleum coke produced by the present invention would have the following results:

**Basis =  $1.0 \times 10^9$  Btu/Hr Heat Release Rate as Input**

<b><u>Fuel Characteristics</u></b>		<b><u>Current Coal</u></b>	<b><u>Upgraded coke</u></b>	<b><u>Results</u></b>
VCM	(%wt)	31.5	16.0	49%
Lower				
Ash	(%wt.)	50.4	0.3	99+%
Lower				

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Heating Value (Mbtu/lb)	3.9	15.3	290% Higher
Fuel Rate (Mlb/Hr)	254	65.4	74% Lower

**Pollutant Emissions: Uncontrolled/Controlled**

Ash Particulates (lb/MMBtu or Mlb/Hr)	128/6.4	0.2/.01	99+% Lower
Sulfur Oxides (lb/MMBtu or Mlb/Hr)	5.1	3.2/.96	37/81% Lower
Carbon Dioxide (lb/MMBtu or Mlb/Hr)	315	210/150	33/52% Lower

This example further demonstrates the beneficial application of the present invention. Again, the upgraded petroleum coke has substantially lower ash and moisture contents, compared to the existing coal. These factors contribute greatly to (1) the ability to burn successfully with lower VCM and (2) a fuel heating value that is 290% higher. In turn, the higher heating value requires a 74% lower fuel rate to achieve the heat release rate basis of one billion Btu per hour in the boiler. As noted previously, this lower fuel rate and the softer sponge coke substantially reduce the load and wear on the fuel processing system, while increasing the pulverizer efficiency and improving combustion characteristics.

The ash particulate emissions (ash from the fuel) are >99+% lower than the existing coal, due to the lower ash content and higher fuel heating value. Consequently, fuel switching to the upgraded coke unleashes >99% of the capacity in the large, existing particulate control device. Part of this excess capacity can now be used for the control of sulfur oxides via retrofit SOx FGC technology.

In this example, dry sorbent injection into the combustion system with the excess capacity of the existing PCD is sufficient to achieve the desirable sulfur oxides control. Dry

Basis =  $1.0 \times 10^9$  Btu/Hr Heat Release Rate as Input

<u>Fuel Characteristics</u>	<u>Current Coal</u>	<u>Upgraded coke</u>	<u>Results</u>
VCM (%wt)	40.8	16.0	61% Lower
Ash (%wt.)	5.2	0.3	94% Lower
Moisture (%wt.)	23.4	0.3	99% Lower
Sulfur (%wt)	0.44	0.65	48% Higher
Heating Value (Mbtu/lb)	9.5	15.3	61% Higher
Fuel Rate (Mlb/Hr)	105	65.4	38% Lower

**Pollutant Emissions: Uncontrolled/Controlled**

Ash Particulates (lb/MMBtu or Mlb/Hr)	5.5/.3	0.2/.01	97% Lower
Sulfur Oxides (lb/MMBtu or Mlb/Hr)	0.92	0.85	8% Lower
Carbon Dioxide (lb/MMBtu or Mlb/Hr)	277	210/190	23/31% Lower

This example further demonstrates the beneficial application of the present invention. Again, the upgraded petroleum coke has substantially lower ash and moisture contents, compared to the existing coal. These factors contribute greatly to (1) the ability to burn successfully with lower VCM and (2) a fuel heating value that is 61% higher. In turn, the higher heating value requires a 37% lower fuel rate to achieve the heat release rate basis of one billion Btu per hour in the boiler. As noted previously, this lower fuel rate and the softer sponge coke substantially reduce the load and wear on the fuel processing system, while increasing the pulverizer efficiency and improving combustion characteristics.

In this example, the desulfurized petroleum coke of the present invention is sufficient to achieve very low sulfur oxide emissions (<1.25 lb/MMBtu). In fact, the desulfurized coke achieves 8% lower emissions (i.e. .85 vs. .92 lb/MMBtu) than this very low sulfur, western coal, even though the desulfurized coke has 50% higher sulfur content. Consequently, the

emissions control. Replacement of half of this coal (i.e. 50% by weight) with a high-sulfur petroleum coke produced by the present invention would have the following results:

**Basis =  $1.0 \times 10^9$  Btu/Hr Heat Release Rate as Input**

<u>Fuel Characteristics</u>	<u>Current Coal</u>	<u>50/50 Coal/Coke</u>	<u>Results</u>
VCM (%wt)	40.2	28.1	32% Lower
Ash (%wt.)	9.1	4.7	48% Lower
Moisture (%wt.)	5.2	2.8	46% Lower
Sulfur (%wt)	2.3	3.3	43% Higher
Heating Value (Mbtu/lb)	12.5	13.9	11% Higher
Fuel Rate (Mlb/Hr)	79.7	72.6	9% Lower

**Pollutant Emissions: Uncontrolled/Controlled**

Ash Particulates (lb/MMBtu or Mlb/Hr)	7.3/0.7	3.8/0.4	43% Lower
Sulfur Oxides (lb/MMBtu or Mlb/Hr)	3.7/3.7	4.7/1.4	62% Lower
Carbon Dioxide (lb/MMBtu or Mlb/Hr)	216	210	3% Lower

This example further demonstrates the beneficial application of the present invention. The 50%/50% mixture of the existing coal and upgraded petroleum coke has significantly lower ash and moisture contents, compared to the existing coal. These factors contribute greatly to (1) the ability to burn successfully with lower VCM and (2) a fuel heating value that is 11% higher. In turn, the higher heating value requires a 9% lower fuel rate to achieve the heat release rate basis of one billion Btu per hour in the boiler. As noted previously, this lower fuel rate and the softer sponge coke substantially reduce the load and wear on the fuel processing system, while increasing the pulverizer efficiency and improving combustion characteristics.

The ash particulate emissions (ash from the fuel) are >43% lower than the existing

Another process of the present invention produces modified petroleum coke with adsorbent characteristics (with or without steam activation) that can be effectively used for carbon adsorption in combustion processes. In a manner similar to steam activation, the combustion process itself can potentially activate the unburned coke char and promote carbon adsorption mechanisms in the flue gas. The relative quantity of this adsorption carbon from unburned premium petroleum coke can be adjusted by controlling the fuel blend, pulverization fineness, excess air, and/or other parameters of the combustion process. Alternatively, other activated carbon (e.g. see above paragraph) can be added to the fuel or the flue gas to provide higher concentration of activated carbon in the flue gas. In this manner, the unburned premium petroleum coke and/or used adsorption carbon from the present invention can adsorb mercury, dioxins, furans, other air toxics, and other undesirable pollutants from the flue gas, including carbon dioxide, SOx, and NOx. The presence of sulfur, available in the coke, can enhance the adsorption of mercury, a growing concern of power generation facilities. In this manner, the premium coke can achieve further reduction of environmental emissions from the combustion process.

**7. Use of Premium "Fuel-Grade" Petroleum Coke: Optimized Environmental Embodiment:**

The various methods and embodiments of the present invention, used to control environmental emissions, can also be used to optimize the overall environmental controls for specific combustion applications. In this manner, an existing combustion facility can be modified to produce the optimal combination of environmental controls to meet or exceed environmental regulations. The following embodiment provides a means (1) to produce an upgraded petroleum coke that not only achieves the basic objectives of this invention, but (2) to also optimize the various environmental control options for various undesirable flue gas components and solid wastes.